

Method Improvements in Thermal Analysis of Hypersonic Leading Edges



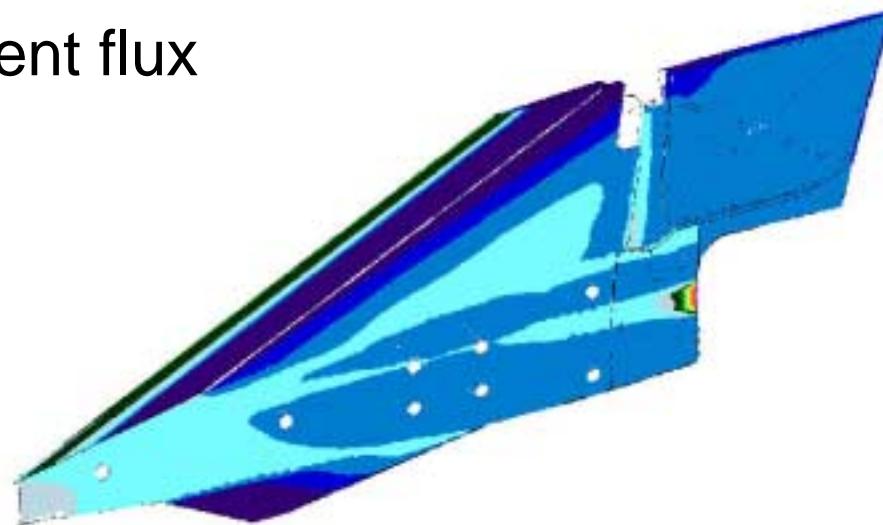
Ruth M. Amundsen
NASA Langley Research Center
presentation at TFAWS
Sept 15, 1999

Agenda

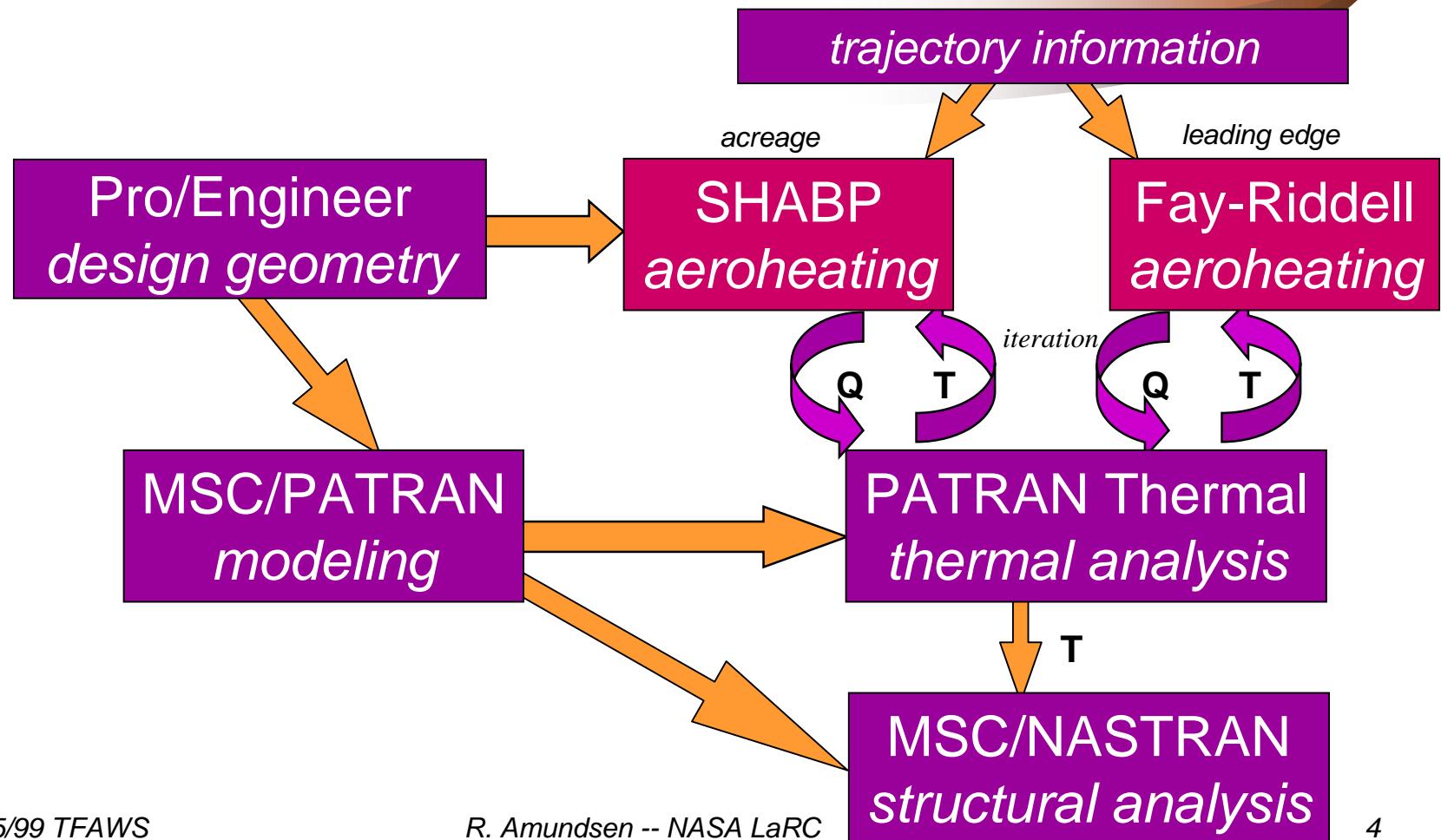
- Background
- Heat flux import
- Grid structure
- Adjustments
- Verification
- Conclusions

Background

- Need for process
 - Robust thermal analysis required for structural prediction
 - Hypersonic aerodynamic heat loads and factoring
 - Time and space dependent flux
 - Complex geometries



Design/Analysis Process



General method

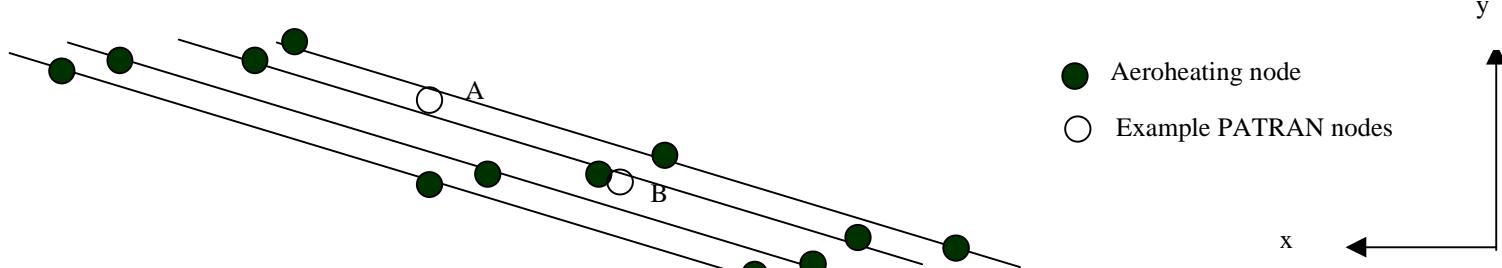
- Import of text aeroheating loads files
- Conversion to PATRAN model through ulib subroutines
- Interpolation in both space and time
- Described at TFAWS 98

Heat flux import

- Heat flux rather than h_c imported
- Benefits
 - Direct value from aeroheating software
 - Direct application of margins to true flux
- Changes
 - Uses umicro.f routine
 - Iteration between flux and temperature more critical

Grid structure

- Aeroheating grid coarse, highly swept
- Interpolation must capture severe gradient normal to leading edge
- Cannot use closest physical point, or x/y co-ord to interpolate



Grid direction

- Aeroheating grid direction follows flow direction, not physical axes
- Position variable may be increasing, decreasing or both in each array
- Units, x/y, origin all may be different than PATRAN model

Grid sensitivity



- Interpolation software adapts to grid sweep, directionality
 - Node location done by iterative calculations of position relative to aero grid lines
 - Interpolation based on effective distance from leading edge
- PATRAN mesh can be structured or not

Flux adjustments

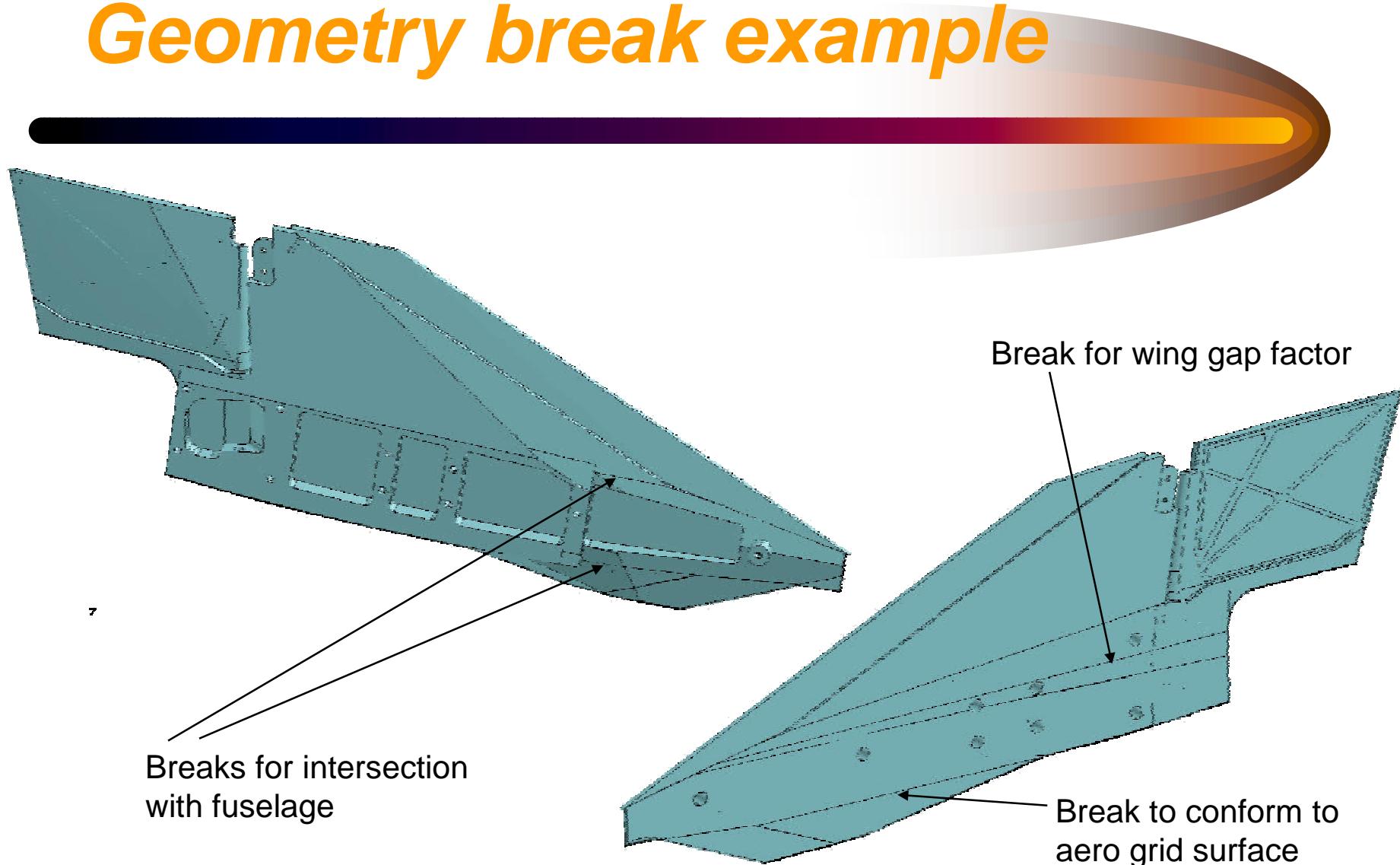
- Factors as function of time or space coded into routines
- Some factors a function of surface (e.g., trailing edge)
- Flux modification near leading edge to replace unreliable values
- Geometry breaks facilitate load application
 - break surfaces and re-assemble solid

Geometry breaking



- Pro/E geometry imports as B-rep solid
- Disassemble to surfaces
- Break surfaces via point, plane, etc.
- Re-assemble solid with all required faces

Geometry break example



Leading edge method

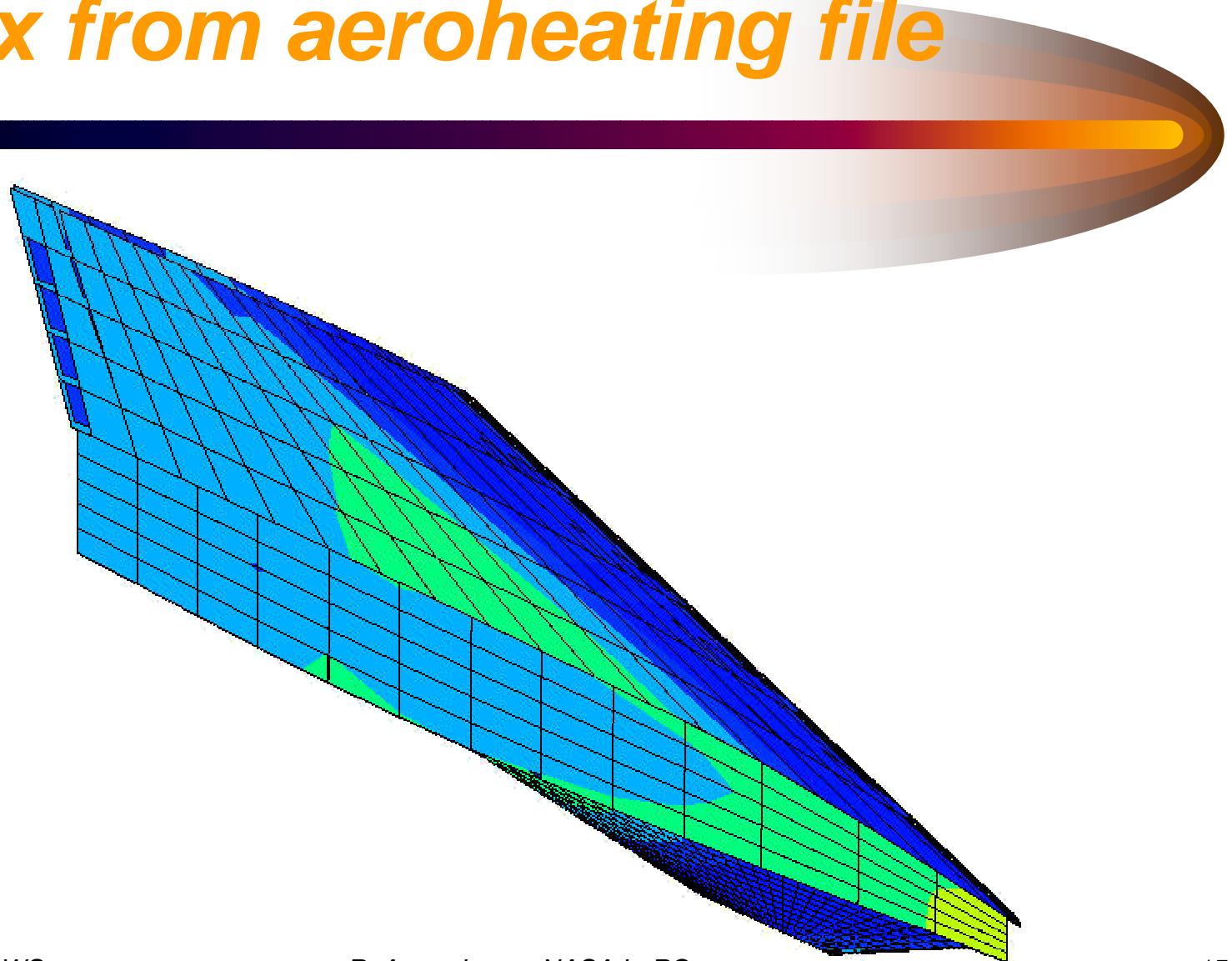
- Fay-Riddell used to calculate flux
 - input: trajectory, radius, sweep angle, body angle, reference skin temperature
- Alter in PATRAN for local temperature
 - use product of three functions

$$Q_{node} = Q_{ref} \frac{T_{stag} - T_{node}}{T_{stag} - T_{ref}} [Q_{ref}] * \left[\frac{1}{T_{stag} - T_{ref}} \right] * [T_{stag} - T_{node}]$$

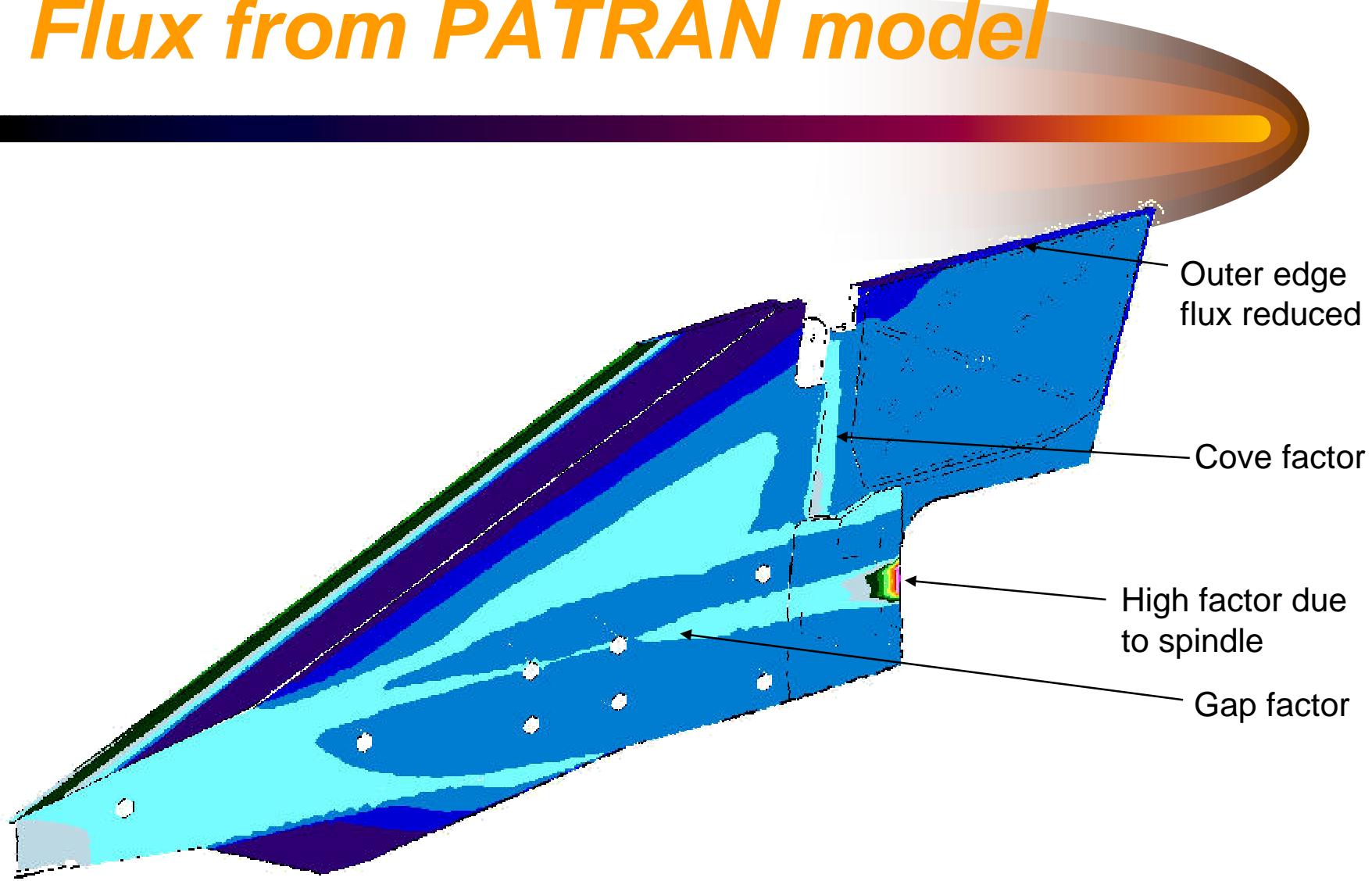
Verification of flux

- PATRAN Thermal plots nodal heat (not flux)
- To plot flux:
 - nodal heat from results file
 - nodal area in qmacro file
 - compute flux, import through spreadsheet function
- Compare visually or via spreadsheet

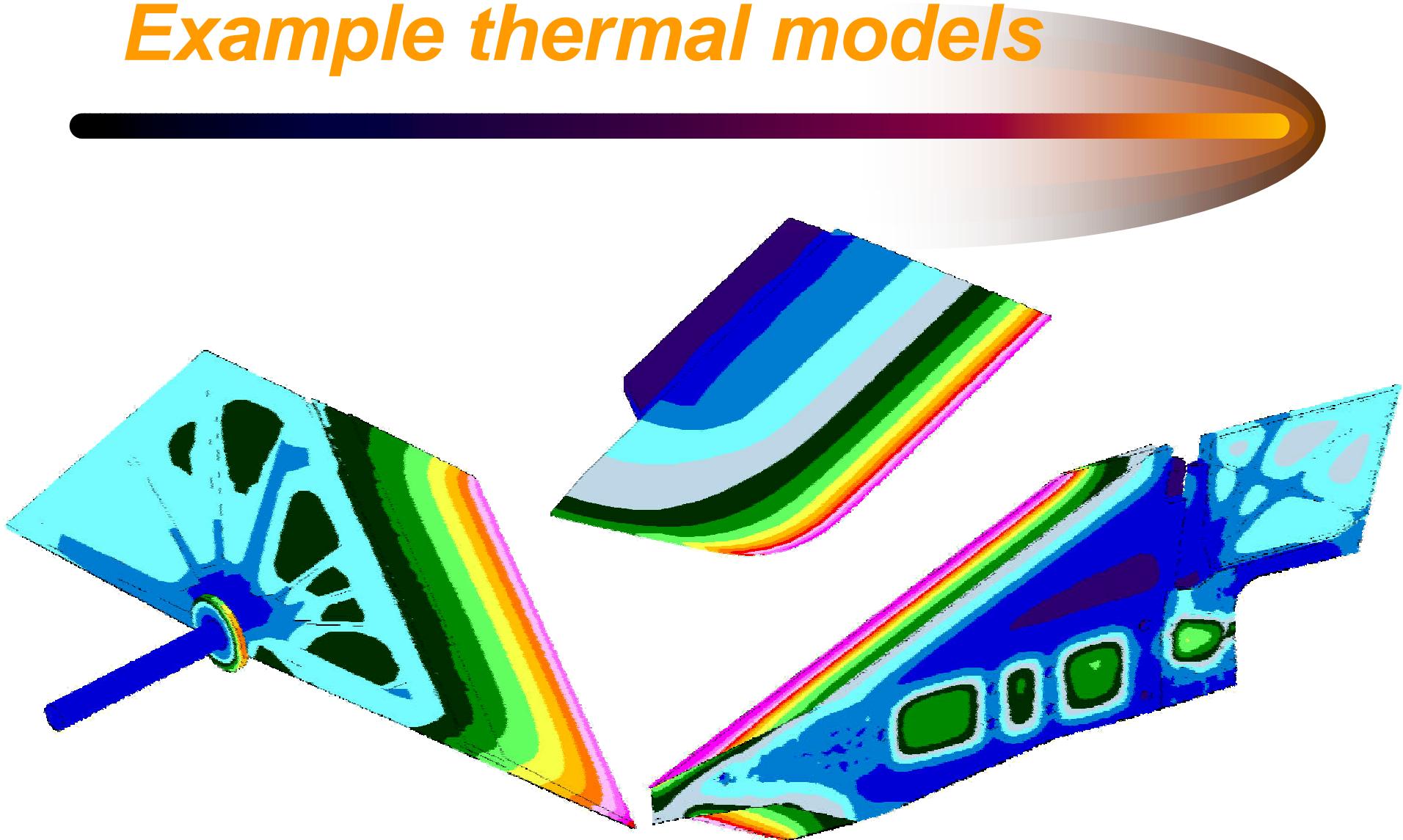
Flux from aeroheating file



Flux from PATRAN model



Example thermal models



Conclusions



- Interpolation software extremely valuable in hypersonic leading edge analysis
 - Robust 3D thermal analysis of complex forms
 - Necessary factors easily incorporated
 - Allows robust thermal stress/strain analysis
- Other helpful developments
 - Geometry breaking for load application
 - Leading edge flux application method
 - Flux verification